CHAPTER ONE

INTRODUCTION

1.1 Background

A very pressing matter in any engineering field in the 21st century is the energy consumption. As the amount of non-renewable sources like petroleum and coal are forecasted to gradually decrease in future, researchers have been highly engaged in developing energy-efficient systems. Energy efficiency denotes a system which works with least wasted effort (energy). It is the idea of doing the same work with less consumption of energy. An example can be fluorescent lamps which are more efficient than Tungsten lamps since they consume lesser electricity to give same amount of light.

While transporting liquid in pipes, energy loss due to friction between pipe wall and liquid molecules and also within liquid due to its viscous effects can be seen in considerable amount. Therefore researches are done to decrease the frictional force and ultimately decrease the energy loss.

1.1.1 Polymers:

Polymers are a large class of materials consisting of many small molecules (called monomers) that can be linked together to form long chains, thus they are known as macromolecules. A typical polymer may include tens of thousands of monomers. Because of their large size, polymers are classified as macromolecules.[1]

The polymer chains can be free to slide past one another (thermoplastic) or they can be connected to each other with cross links (thermoset). Thermoplastics (including thermoplastic elastomers) can be reformed and recycled, while thermosets (including cross linked elastomers) are not re workable.

1.1.2 Thermoplastics:

Polymers that flow when heated and easily reshaped and recycled. This property is due to presence of long chains with limited or no cross links. In a thermoplastic material the very long chain-like molecules are held together by relatively weak Vander Waals forces. When the material is heated the intermo-

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lecular forces are weakened so that it becomes soft and flexible and eventually, at high temperatures, it is a viscous melt (it flows). When the material is allowed to cool it solidifies again.

Such as polyethylene (PE), polypropylene (PP), Random polypropylene (PPR), poly (vinyl chloride) (PVC), polystyrene (PS) and poly (ethylene terephthalate) (PET)

1.1.3 Thermosets:

Decompose when heated then cannot be reformed or recycled. Presence of extensive cross links between long chains induces decomposition upon heating and renders thermosetting polymers brittle.

A thermosetting polymer is produced by a chemical reaction which has two stages. The first stage results in the formation of long chain-like molecules similar to those present in thermoplastics, but still capable of further reaction. The second stage of the reaction (cross linking of chains) takes place during molding, usually under the application of heat and pressure. During the second stage, the long molecular chains have been interlinked by strong covalent bonds so that the material cannot be softened again by the application of heat. If excess heat is applied to these materials they will char and degrade.

Such as epoxy, unsaturated polyesters, phenol-formaldehyde resins, and vulcanized rubber.

1.1.4 Elastomers:

The polymer chains in elastomers are above their glass transition at room temperature, making them rubbery. Can undergo extensive elastic deformation.

Elastomeric polymer chains can be cross linked, or connected by covalent bonds. Cross linking inelastomers is called vulcanization, and is achieved by irreversible chemical reaction, usually requiring high temperatures.[[2]]

UN vulcanized natural rubber (polyisoprene) is a thermoplastic and in hot weather becomes soft and sticky and in cold weather hard and brittle. It is poor-

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Source Ref 2

ly resistant to wear. Sulfur compounds are added to form chains that bond adjacent polymer backbone chains and cross links them. The vulcanized rubber is a thermosetting polymer.

Cross linking makes elastomers reversibly stretchable for small deformations. When stretched, the polymer chains become elongated and ordered along the deformation direction. This is entropically unfavorable. When no longer stretched, the chains randomize again. The cross links guide the elastomer back to its original shape.

For example: natural rubber (poly-isoprene), poly-butadiene (used in shoe soles and golf balls), poly-isobutylene (used in automobile tires), butyl rubber (pond and landfill linings), styrene butadiene rubber – SBR (used in automobile tires) and silicone.

1.1.5 Plastic pipes

Galvanized pipes was replaced by plastic pipes made from (PVC,PE.PP,PS) before some years ago in different applications separately in water and irrigation systems ,PP-R pipes are one of plastic pipes intended to be used for the installation of warm and cold hygienic sanitary water. Irrigation of the greenhouses and gardens, shipment of pressure air, vacuum installations, in chemical industry for the flow of various fluids, as well as for the transportation of the sea water and highly abrasive fluids. They are commonly being used for radiator heating, as well as for the floor heating and cooling systems. Their low weight and high tolerance to vibrations are suitable for applications in trains, ships, trucks and camping trailers, in aggressive environment and on unstable ground.[[3]] The advantages of PPR plastic pipes ,Long life time thanks to their resistance to environmental influences, non corrosive, Impossible perforation caused by "stray currents" , Low pressure losses because of the smooth surface, which do not allow the deposit of stone layer on the pipe walls, turbulences or friction, They are completely nontoxic and are in compliance with stand-

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ards for the transfer of potable water, high capability of thermal and sound iso-lation, energy saver, they reduce the risk of condensation to a minimum, which is the characteristic of the metal installation, Great welding ability .All parts can be connected with welder or electrical socket, Low weight (9time lighter than steel) which makes it easier for transportation and handling and inexpensive cost.

A PPR pipes model are used in this thesis to investigate the problem of pressure drop and flow constants of pipes and fitting. The model is based on selected 1/2 inch PPR pipe, elbows and valve.In order to predict that in model where used experimental and available data in literature.

1.2 Objectives

- To design fluid model for PPR pipes and fitting.
- To get parameters and coefficients of PPR pipes and fitting thatafterrun experimental.
- To Calculate theoretical and experimental losses
- To compare the friction loss analytically and experiments .

CHAPTER TWO

LITERATURE REVIEW

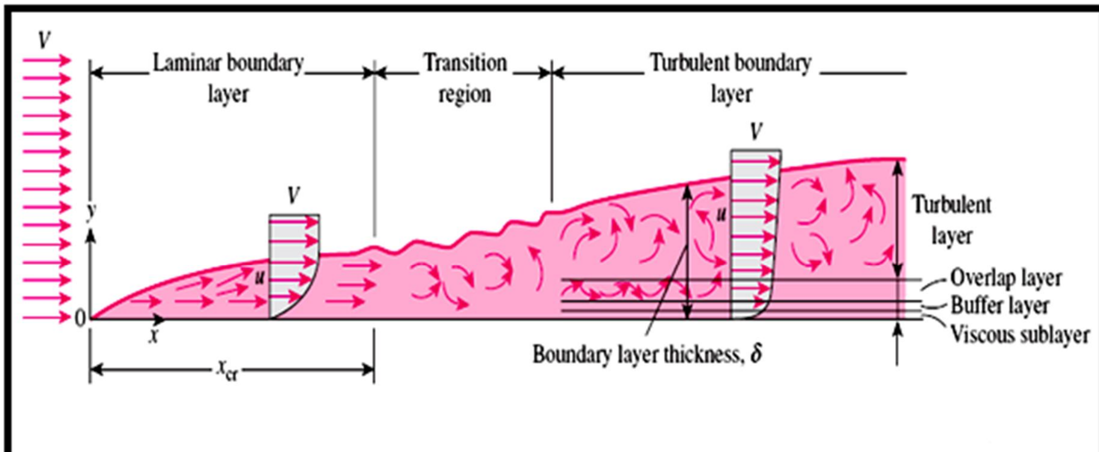
2.1 Introduction :

The pipes are closed conduits with circular a cross-section are used to flaw water, oil and gas.

A flow of fluid in a pipe can have different characteristics. Pipe flow is a type of flow where the flowing fluid has no free surface and pressure on the pipe is the pressure of the liquid. Liquid flows due to pressure differenc between two ends of pipe. Example of this flow is: drinking water pipes. In open channel flow, the liquid has free surface and pressure on pipe is atmospheric. Here, the movement of liquid is due to gravity. Example is drainage pipe

A flow is also known as internal flow where the pipes is assumed to be completely filled with the fluid. a fluid motion is generated by pressure difference between two points and is constrained by the pipe walls. The direction of the flow is always from a point of high pressure to a point of low pressure. a Flow in pipes can be divided into two different regimes, i.e. laminar and turblence[4]

A The experiment to differentiate between both regimes was introduced in 1883 by Osborne Reynolds (1842 – 1912), an English physicist who is famous in fluid experiments in early days is shown infigure [4]



The development of the boundary layer for flow over a flat plate, and the different flow regimes.

Fig2.1 : Experiment for Differentiating Flow Regime.

- From Fig.1, the dye is used to mark the flow path of the fluid. In order to demonstrate the transition between laminar and turbulent regime, the – Q is varied.

- For a constant diameter pipe the cross sectional area is also constant. The velocity V is directly proportional to Q .

- For Laminar regime, the flow velocity is kept small ,thus the generated flow is very smooth which is shown as straight tiny line formed by the dye.

- When the flow velocity is increased, the flow becomes slightly unstable such that it contains some temporary velocity fluctuation of fluid molecules and this mark the transition regime between both regimes. Then, the velocity can be increased further so that the fluid flow is completely unstable and the dye is totally mixed with the surrounding fluid. This phenomenon is known as turbulence.

- This graph clearly shows a smooth velocity of Laminar flow and a fluctuated velocity for turbulent flow.

- Clearly , one of the main critical parameters that determine the flow regimes is the velocity.

- This parameter, together with fluid properties, namely density p and dynamic viscosity m ,as well as pipe diameter D, forms the

dimensionless Reynolds number, that is.

$$Re = \frac{\rho v d}{\mu} = \frac{\text{Inertia}}{\text{Viscousforces}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.1)$$

- From Reynolds' experiment, he suggested that Re<2000 for laminar flows and Re>4000 for turbulent flows. The range of Re between 2000 and 4000 represents transitional flows .

2.2 Development of flow in pipes

- In many cases of pipe flows, it may begin from a tank as shown in Figure2.

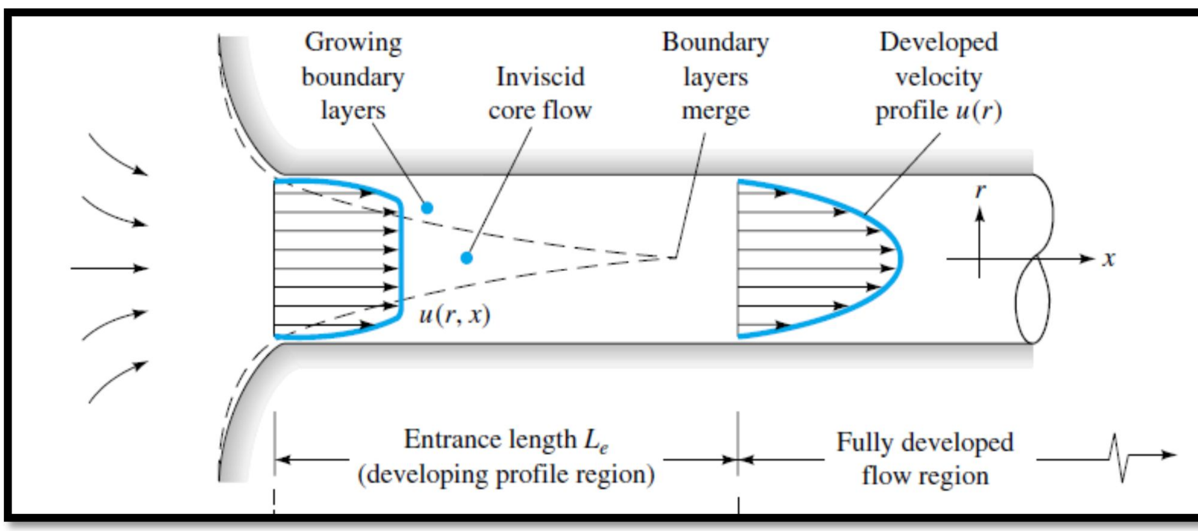


Fig 2.2: Velocity profiles at the Entrance and fully Development Regions

- The common velocity profile for laminar pipe flow is parabolic. However, at a position in the pipe where the fluid just exits from the reservoir, the velocity profile is almost uniform.

- This uniform flow can also be seen as a representation of in viscid flow since the fluid molecules has no relative motion from one to another. The transition from the initially uniform flow and a fully developed parabolic occurred in the entrance region. In this region, the flow is formed by a mixture between the following two regions :-

1- In viscid core, where the velocity profile is uniform and the viscous effect is negligible.

2- Boundary layer, where it allows velocity variation from pipe walls with no-slip condition to the core and the viscous effect is dominant.

- The entrance region can be following formulate for both regimes :

The entrance region can be represented by entrance length, $l_e$which can be empirically determined by the following formulae for both regimes:

$$\text{Laminar}: \frac{l_e}{D} = 0.06Re -------- (2.2)$$

$$\text{Turbulant}: \frac{l_e}{D} = 4.4(Re)^{\frac{1}{6}} ------ (2.3)$$

Pressure Drop in a Pipe 2.2.1

Due to different boundary layer thickness in the in viscid core, the pressure distribution behaves non-linearly in this region and the pressure slope is not constant as shown in Figure 3. However, after the flow is fully developed, the slope becomes constant and the pressure drop Δp is directly caused only by viscous effect.

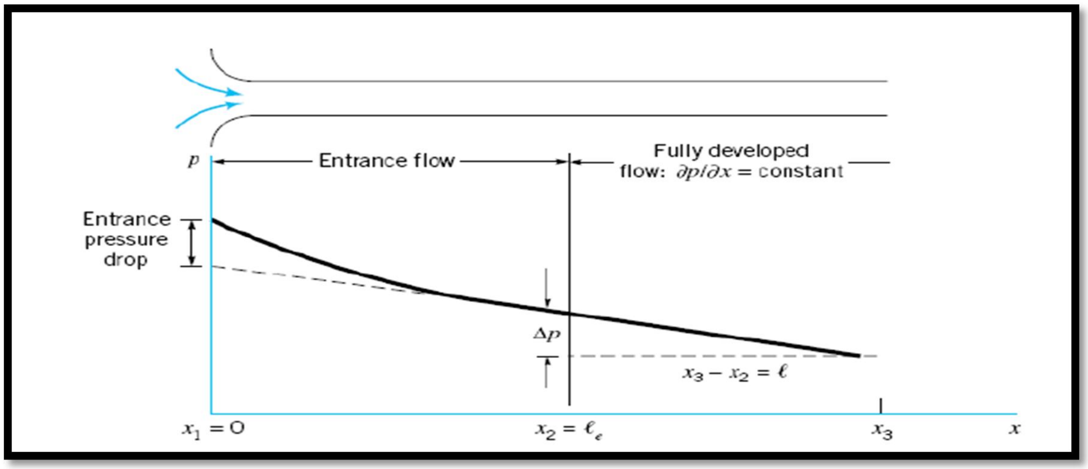


Fig 2.3: Pressure Distributions in a Horizontal Pipe

By projecting the graph back towards the tank, we can estimate the pressure drop due to entrance flow. Hence, by using the Bernoulli equation with losses, the pressure value at all position along the same pipe can be calculated.

From Figure 3, we can also deduce that there are two types of pressure loss; the first is known as friction or major loss and is caused by friction which reduces the fluid pressure linearly with gradient -Δp/ℓ , and the second is known as minor loss and is generated by sudden change in flow direction as in the entrance flow.

The friction loss is proportional to the pipe length, while minor losses can be emulated by sudden pressure drop. In this case, we can summarise that minor losses represent pressure losses in developing flow which is experiencing disturbances and changes in internal pipe geometry.

Then apply the modified Bernoulli equation with head loss hL between two points along a no horizontal pipe of length ℓ with constant diameter D, shown inFigure[2.4]. The modified Bernoulli equation can be written as :

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2} + z_2 + h_L - (\text{Energy Equation}) --------(2.4)$$

$$\frac{V_1}{V_2} = \frac{D_2^2}{D_1^2} - (Mass\ Equation) --------(2.5)$$

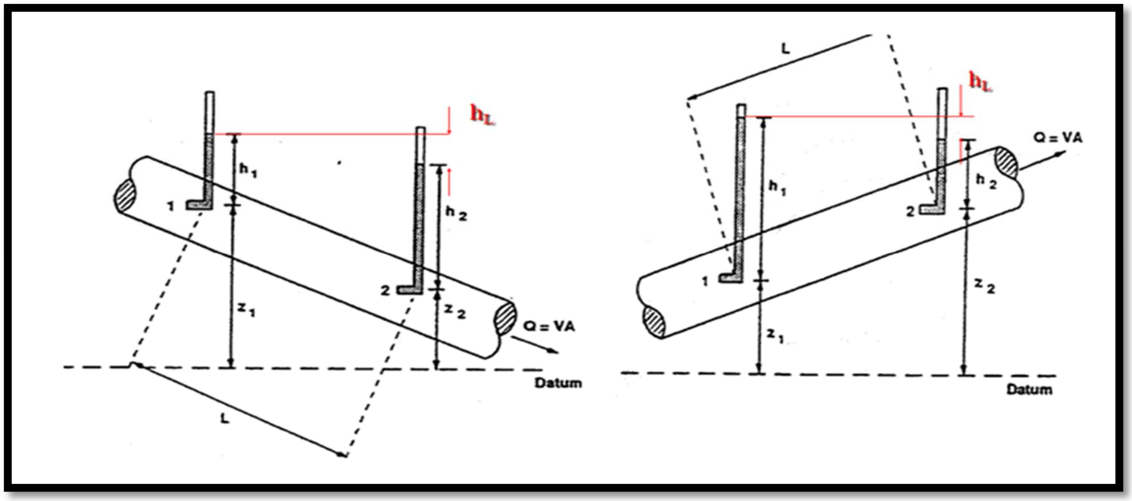


Fig 2.4: Flow in no horizontal pipe

For constant diameter and horizontal pipe, shown in Figure 5, V1 = V2 and z1= z2. Then, the head loss can be formulated as

$$h_L = \frac{p_1 - p_2}{\rho g} = \frac{\Delta p}{\rho g} ------(2.6)$$

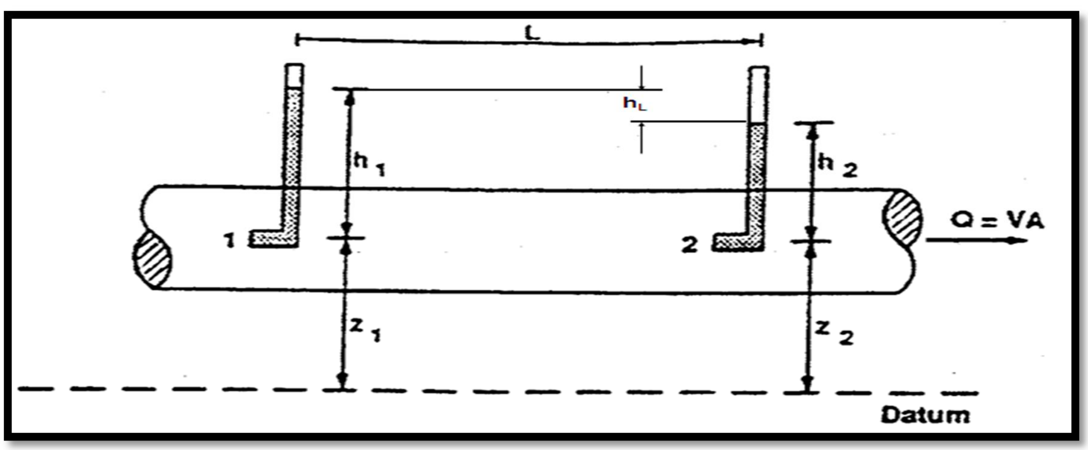


Fig 2.5: Flow in horizontal pipe

Pressure (Head) Loss in Pipes

For a steady flow in pipe, pressure changes are due to

elevation changes

velocity changes due to area changes

Bernoulli is enough by using Equations (4 and 5)

viscous affects (now we will study this in detail)

Pressure (head) loss can be decomposed into two

Major loss: In a constant area pipe, pressure drops in the direction of flow.

Minor loss: Pressure drops in flows through valves, tees, elbows, and other area change

2.2.2 Major Head Loss s.

1. Major Head Loss in the Laminar Pipe Flow 2.

Consider a steady flow in a constant diameter, horizontal pipe Figure 5.

Pressure drop over a length L is :

$$\boxed{\Delta p = f \frac{L}{D} \frac{\rho V^2}{2}}$$ ………………………………………… (2.7)

Where V is the average velocity and f is the friction factor.

$$\boxed{f = \frac{64}{Re_D} = \frac{64\mu}{\rho V D}}$$ ……………………………………………… (2.8)

This pressure drop can also be expressed as hf = $\Delta p/\rho g$ see Eq (6).

- $$\boxed{h_f = f \frac{L}{D} \frac{V^2}{2g}}$$ -(Darcy Equation)………………………………(2.9)

2.Major Head Loss in the Turbulent Pipe Flow

There is no analytical formula for Δp.

Results are based on experimental studies. $\Delta p = \Delta p\,(D, L, \varepsilon, V, \rho, \mu)$

ε is the pipe roughness .

Using the Buckingham-Pi theorem, we can find n – m = 7 – 3 = 4 no dimensional groups.

$$\boxed{\frac{\Delta p}{\rho V^2} = F\left(Re_D, \frac{L}{D}, \frac{\varepsilon}{D}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.10)}$$

or using $hf = \Delta p/\rho g$ the equation (10) become:

$$\frac{2gh_f}{V^2} = F\left(Re_D, \frac{L}{D}, \frac{\varepsilon}{D}\right)$$

$$\boxed{h_f = f\left(Re_D, \frac{\varepsilon}{D}\right)\frac{L}{D}\frac{V^2}{2g}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.11)}$$

Equation (11) describes head loss for a turbulent flow in a constant area pipe.

f is the Darcy friction factor. It depends on Re and ε /D (relative surface roughness).

f can be determined by curve fitting equations through experimental data. There are many different formulations for f.

Blasius Equation (1911): It does not considerε.

$$\boxed{f = 0.3164\, Re_D^{-0.25}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.12)}$$

i. Colebrook Equation (1939):

$$\boxed{\frac{1}{\sqrt{f}} = -2\,\log\left[\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re_D\sqrt{f}}\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.13)}$$

ii. Haaland Equation:

$$\boxed{\frac{1}{\sqrt{f}} = -1.8\,\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.1} + \frac{6.9}{Re_D}\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.14)}$$

iii. Miller Equation:

$$f = 0.25 \ \log\left[\frac{\varepsilon/D}{3.7} + \frac{5.74}{Re_D^{0.2}}\right]^{-2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.15)$$

- The most convenient way to get the friction factor for a turbulent pipe [4] flow is to use the Moody diagram (shown in graph 1).

It is the graphical representation of the Colebrook equation Eq(2.13).

Relative roughness = ε/D

ε = absolute roughness

D = Pipe inside diameter

You need Re and ε/D to read the f value.

ε/D for several commercial pipes is given in table 1.

Note that the laminar friction factor (f = 64/Re) is also shown in the Moody diagram as a straight line.

Moddy diagram has log-log axes. You need to know how to read values from a log axis.

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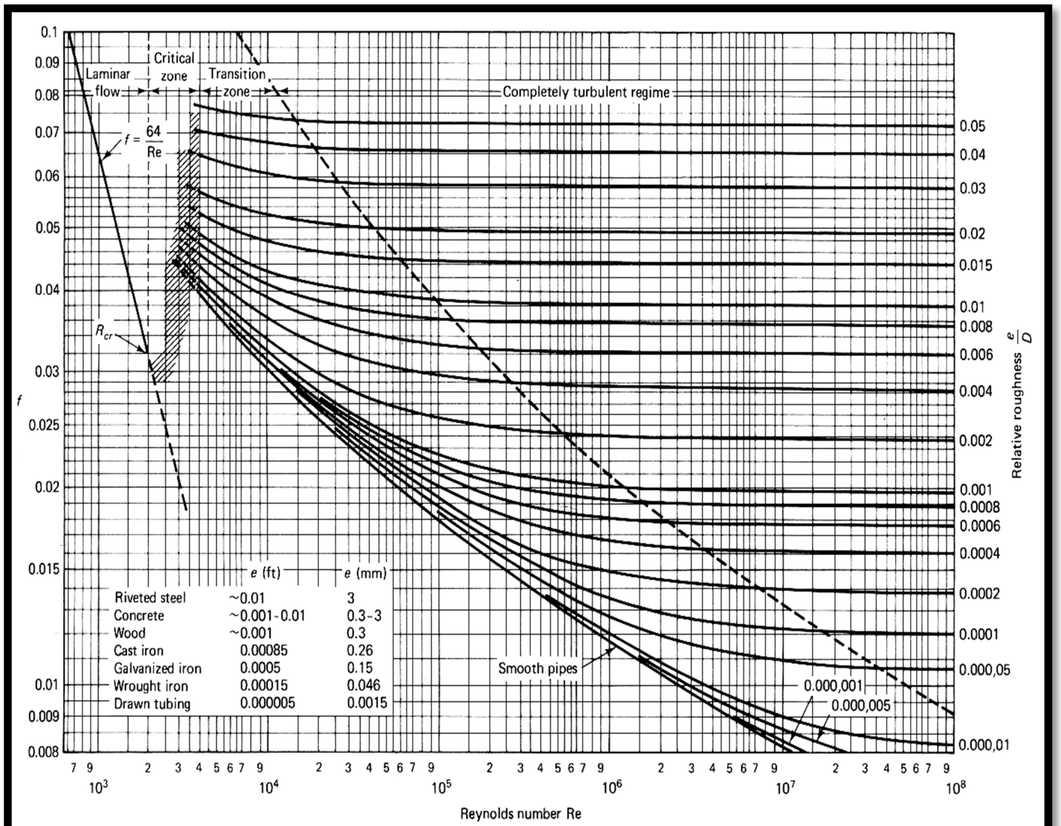

Figure 7.13 Moody diagram. (From L. F. Moody, *Trans. ASME*, Vol. 66, 1944.)

Fig. 2.6: Moody diagrams the friction factor vs. Reynolds number

Material	Surface Roughness, ε	
	feet	meters
PVC, plastic, glass	0.0	0.0
Commercial Steel or Wrought Iron	1.5E-4	4.5E-5
Galvanized Iron	5.0E-4	1.5E-4
Cast Iron	8.5E-4	2.6E-4
Asphalted Cast Iron	4.0E-4	1.2e-4
Riveted Steel	0.003 to 0.03	9.0E-4 to 9.0E-3
Drawn Tubing	5.0E-6	1.5e-6
Wood Stave	6.0E-4 to 3.0E-3	1.8E-4 to 9.0E-4
Concrete	0.001 to 0.01	3.0E-4 to 3.0E-3

Table [2.1]: Table of Surface Rough nesses

2.2.3.Minor Head Losses in Variable Area Parts

Minor head losses in pipelines occur at pipe and fittings such as Tees, Elbows, and Bends, sudden Expansion and contraction of pipe sections, junctions etc.

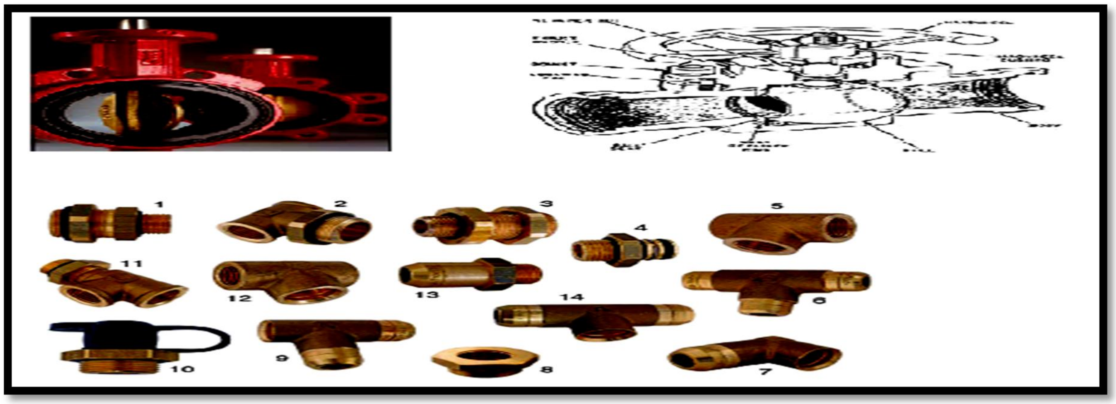

Fig. 2.7: type of fittings

In long pipelines these Minor head losses are often minor in comparison with energy losses due to friction and may be neglected.

In short pipes, however, they may be greater than frictional losses and should be accounted.

Minor losses usually result from abrupt changes in velocity leading to eddy formation which extract energy from the mean flow.

Increase of velocity is associated with small head (energy) losses and decrease of velocity with large head losses

The general formula to calculate the Minor head loss for these variable area parts is :

$$\boxed{h_f = k\frac{V^2}{2g}} \quad \text{.. (2.16)}$$

Where k is the head loss coefficient and V is the average velocity.

V can be either the upstream or the downstream velocity.

Experimental k values can be obtained from tables

2.3 Types of Minor Head Losses

2.3.1 Sudden Expansion

Energy lost is because of turbulence. Amount of turbulence depends on the differences in pipe diameters.

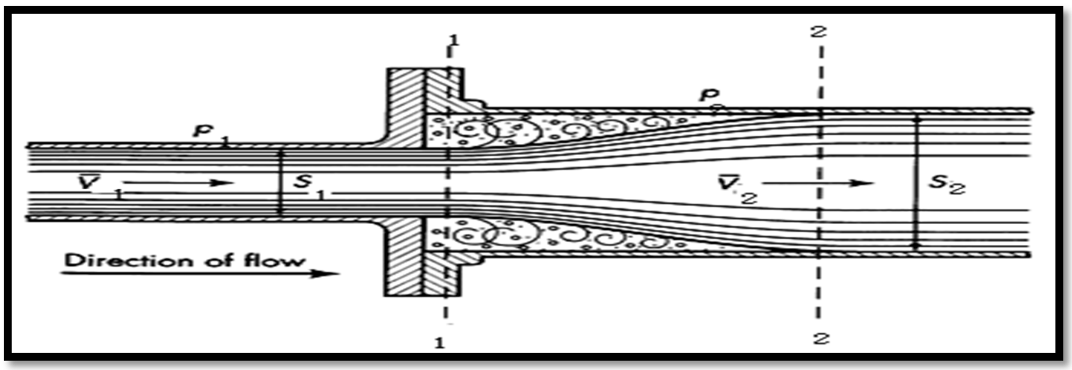

Fig2.8.1: Sudden Expansion Loss

Sudden Expansion Loss coefficient k= k_e and (V=V1) for equation (2.16):

$$h_{fe} = k_e \frac{{V_1}^2}{2} = (1 - \frac{S_1}{S_2})^2 . \frac{{V_1}^2}{2} = (1 - \frac{{D_1}^2}{{D_2}^2})^2 . \frac{{V_1}^2}{2} = (1 - \frac{1}{\left(\frac{D_2}{D_1}\right)^2})^2 . \frac{{V_1}^2}{2}$$

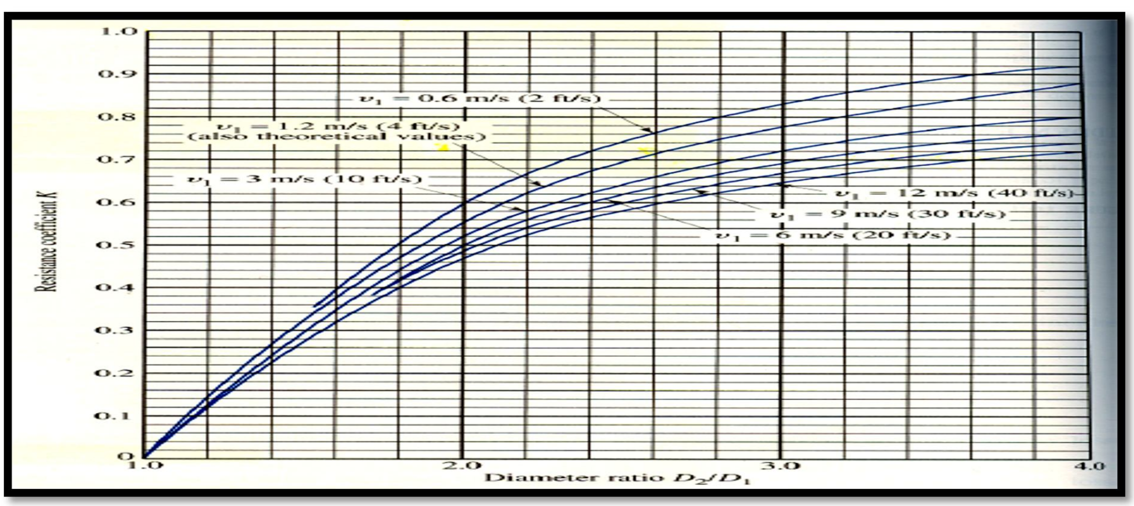

Fig 2.8.2: Sudden Expansion Loss

The values of K have been experimentally determined and provided in blew Graph.

2.3.2 Gradual Enlargement

If the enlargement is gradual (as opposed to our previous case) – the energy losses are less.

The loss again depends on the ratio of the pipe diameters and the angle of enlargement.

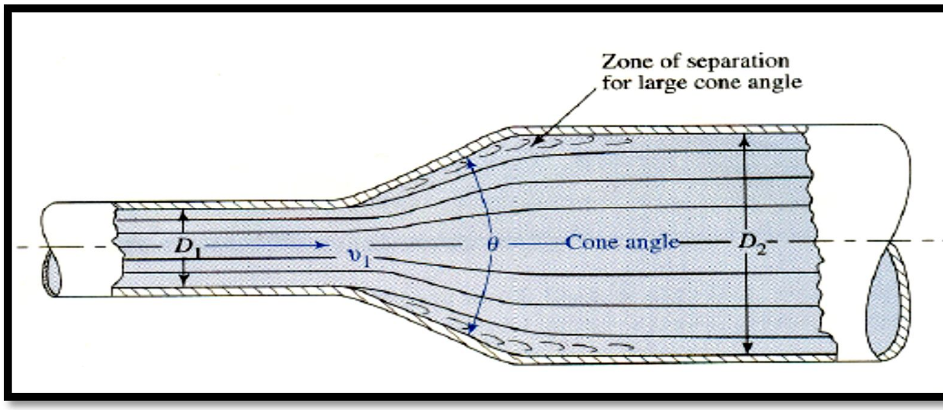

Fig2.9.1: Gradual Enlargement

- K can be determined from below Fig.

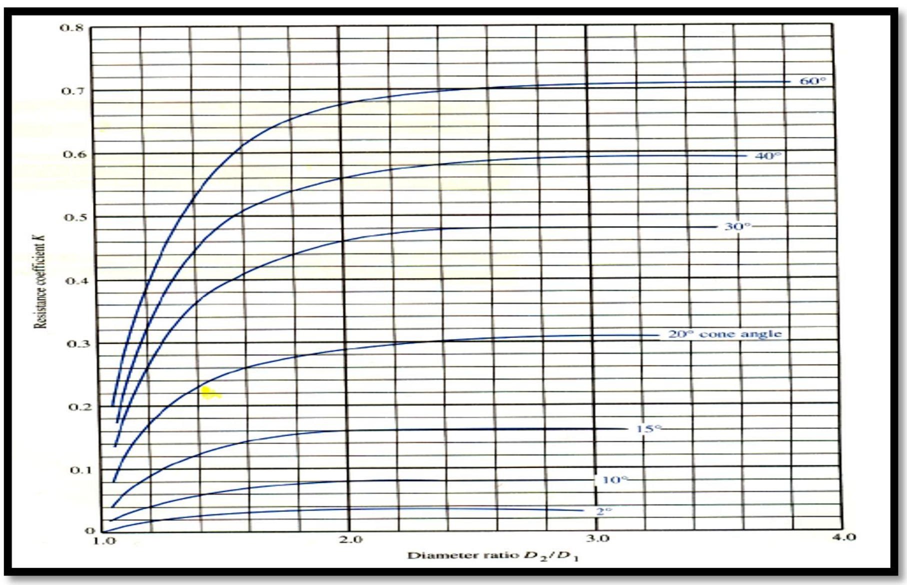

Fig 2.9.2: Gradual Enlargement [5]

If angle increases (in pipe enlargement) – minor losses increase.

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If angle decreases – minor losses decrease, but you also need a longer pipe to make the transition – that means more FRICTION losses.

Minimum loss including minor and friction losses occur for angle of 7 degrees – OPTIMUM angle.

2.2.3 Sudden Contractions

Decrease in pipe diameter.

Loss is given by.

$$h_{fc} = k_c \frac{V_2{}^2}{2} \quad \text{.......} 2.18$$

$$k_c = 0.4\left(1 - \left(\frac{D_2}{D_1}\right)^2\right) \quad \text{.......} 2.19$$

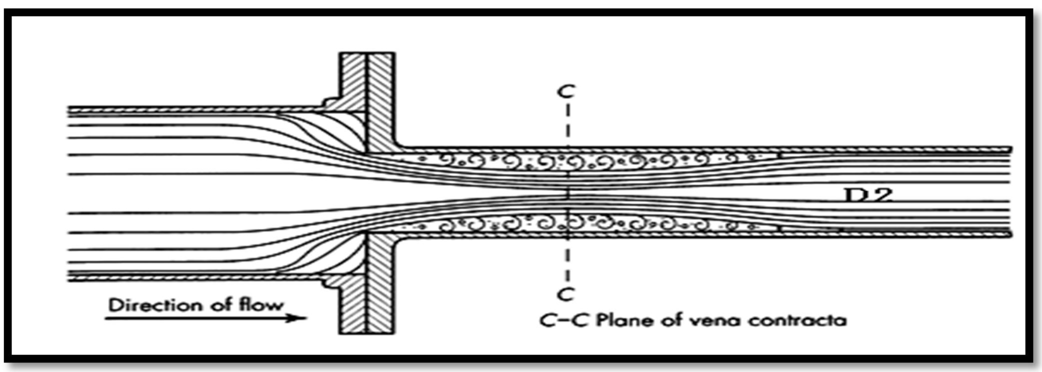

Fig 2.10: Sudden Contractions

The loss is associated with the contraction of flow and turbulence.

For laminar flow experimentally, Kc < 0.1 and hfc is usually neglected.

Turbulent (empirical): $k_c = 0.4\left(1 - \left(\frac{D_2}{D_1}\right)^2\right)$

K can be computed using Fig [2.3] Again based on diameter ratio and velocity of flow

Energy losses for sudden contraction are less than those for sudden expansion.

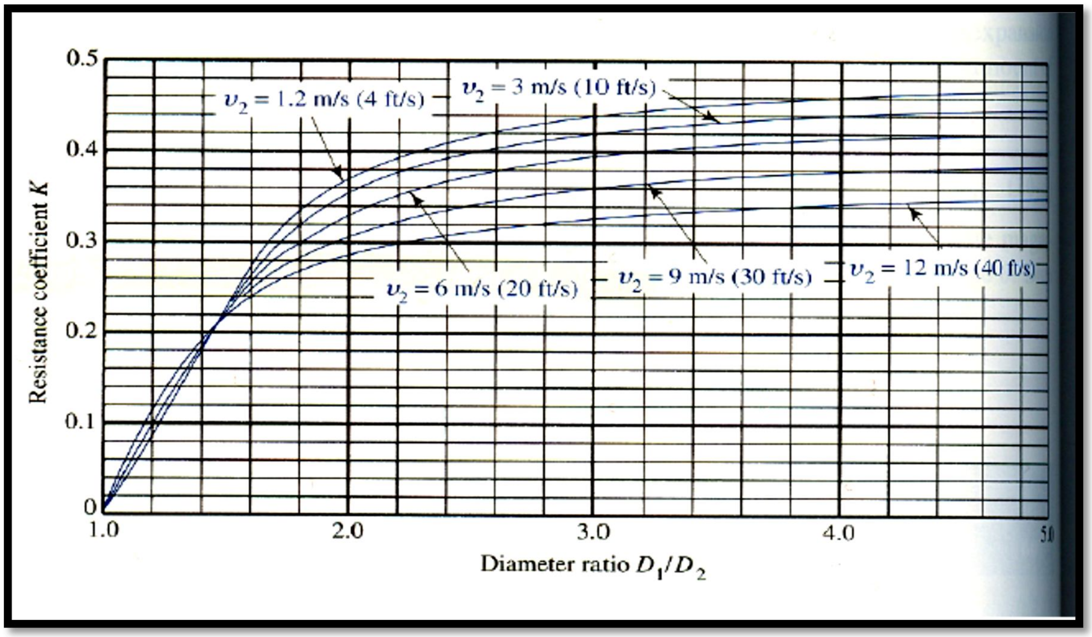

Fig 2.10: Energy losses for sudden Contraction

Again a gradual contraction will lower the energy loss (as opposed to sudden contraction). θ is called the cone angle.

K is given by below Fig.

Note that K values increase for very small angles (less than 15 degrees)

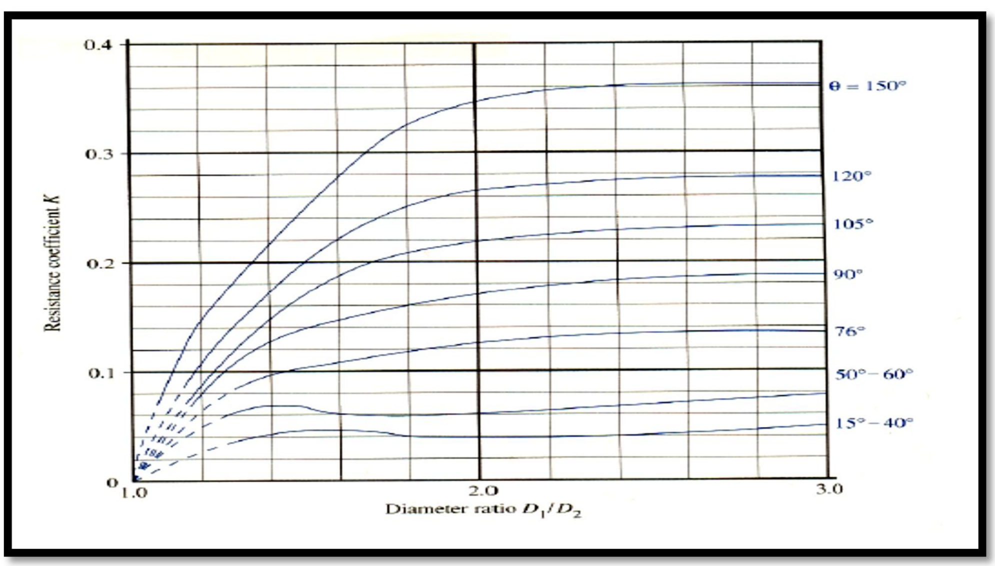

Fig 2.11: gradual contraction

2.2.4 Exit Loss

Case of where pipe enters a tank – a very large enlargement.

The tank water is assumed to be stationery, that is, the velocity is zero.

Therefore all kinetic energy in pipe is dissipated, therefore K =1.0

$h_L = 1.0 * (v_1^2 / 2g)$ ……………………2.20 [6]

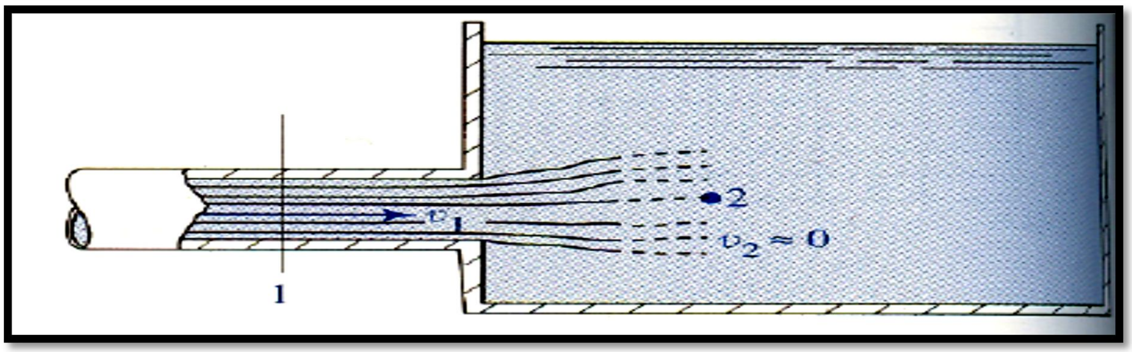

Fig 2.12: Exit Loss

2.2.5 Entrance Losses

Fluid moves from zero velocity in tank to v2

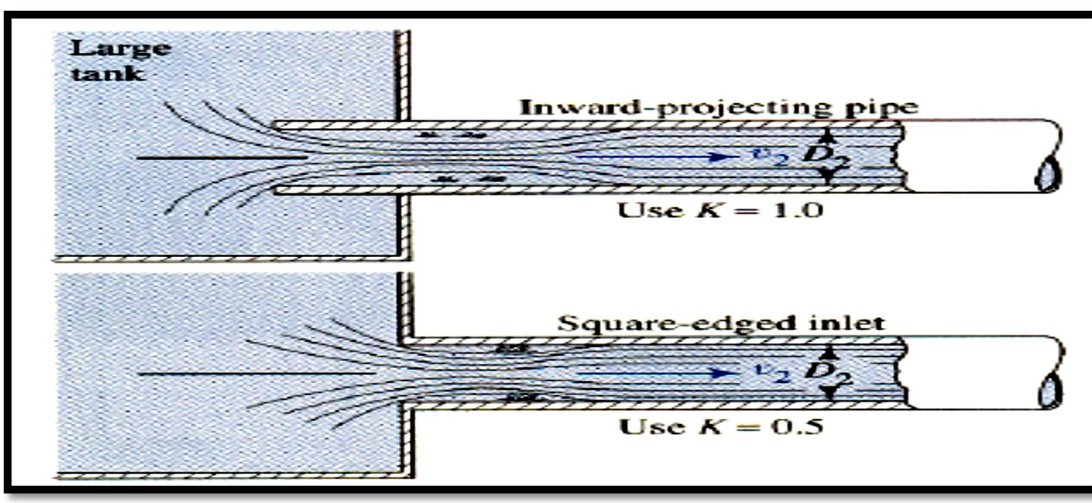

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Fig 2.13.1:EntranceLosses

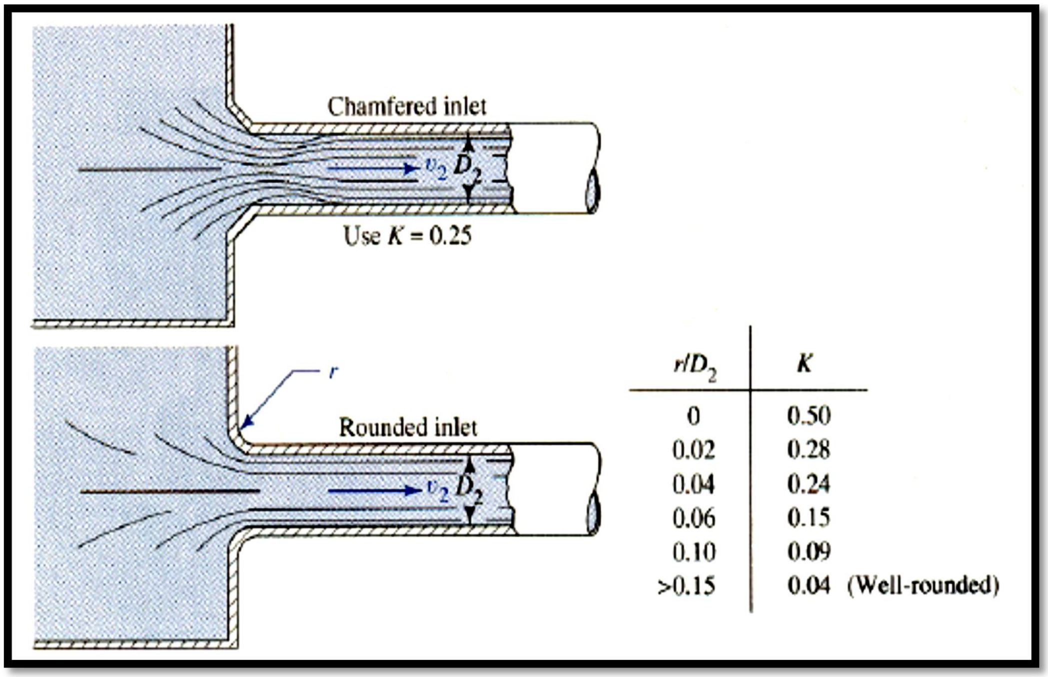


Fig 2.9.2:EntranceLosses

2.4 Head loss at smooth pipe bends

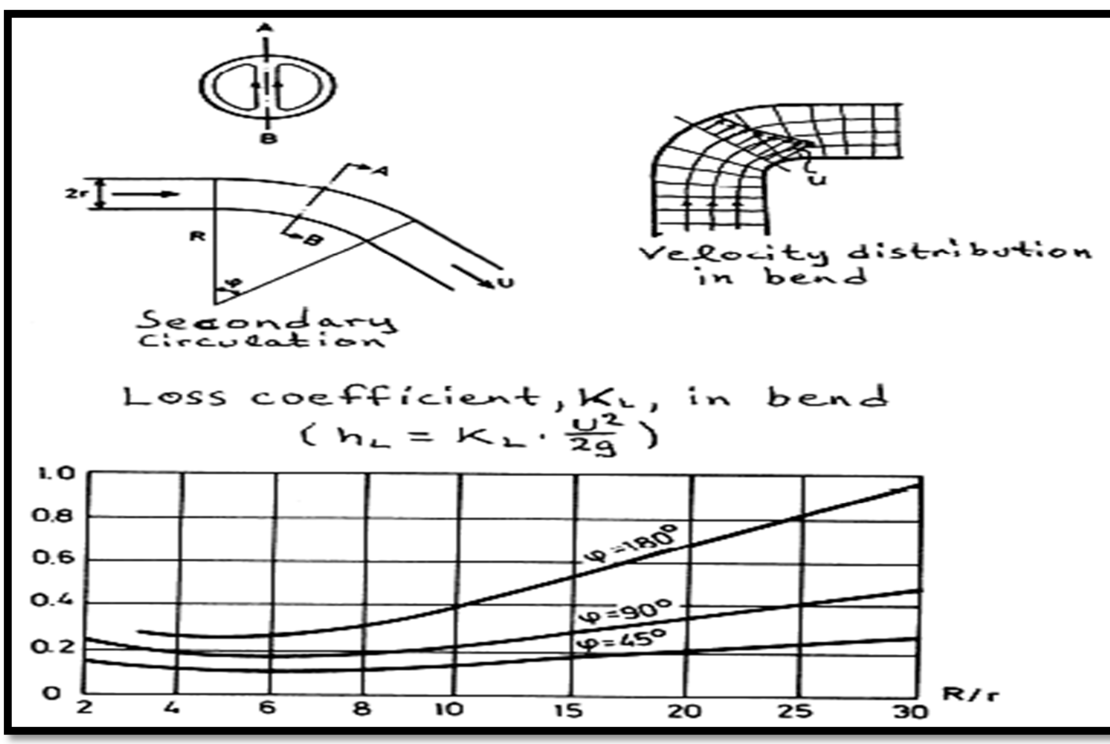


Fig 2.14: Head loss at smooth pipe bends

2.4.1 Loss coefficients at right angle bends

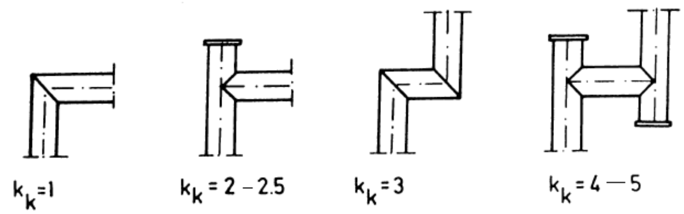


Fig 2.15: Loss coefficients at right angle bends [7]

2.4.2Valves

Function of valve type and valve position.

The complex flow path through valves can result in high head loss (of course, one of the purposes of a valve is to create head loss when it is not fully open).

h_v are the loss in terms of velocity heads.

Fig 2.16:Type of valves

Valve	K
Gate valve, wide open	0.15
Gate valve, 3/4 open	0.85
Gate valve, 1/2 open	4.4
Gate valve, 1/4 open	20

Ref Source 8

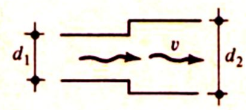
Globe valve, wide open	7.5

Table(2.2) Loss coefficients of valve type and valve position

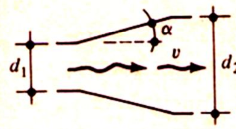
Tables of minor losses

Values of km for use with $h_m = k_m \frac{V^2}{2g}$ ……………..(2.21)

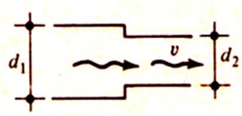
1. *Enlargements and Contractions*



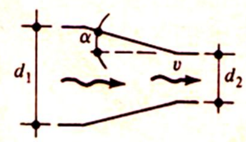
$\frac{d_2}{d_1}$	1.0	1.25	1.50	1.75	2.0	2.25	2.50	2.75	3.0
k_m	0.0	0.32	1.56	4.25	9.0	16.5	27.6	43.1	64.0



	α					
	3°	5°	7.5°	10°	15°	20°
	n					
$\frac{d_2}{d_1}$	0.14	0.20	0.30	0.40	0.70	0.90
1.25	0.04	0.06	0.10	0.13	0.22	0.29
1.50	0.22	0.31	0.47	0.62	1.09	1.40
1.75	0.60	0.85	1.28	1.70	2.98	3.82
2.00	1.26	1.80	2.70	3.60	6.30	8.10
2.25	2.31	3.30	4.95	6.60	11.6	14.8
2.50	3.86	5.52	8.28	11.0	19.3	24.8
2.75	6.03	8.62	12.9	17.2	30.2	38.8
3.00	8.96	12.8	19.2	25.6	44.8	57.6

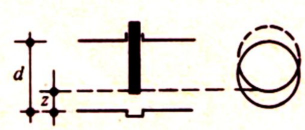


$\frac{d_2}{d_1}$	1.00	0.80	0.60	0.50	0.40	0.35	0.30	0.25
k_m	0.0	0.22	0.35	0.40	0.44	0.45	0.47	0.48



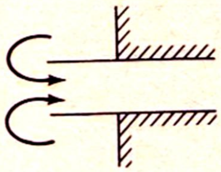
$\frac{\alpha}{d_1}$	2.5°	5°	7.5°	10°	15°	20°	30°
k_m	0.06	0.16	0.18	0.20	0.24	0.28	0.32

2. *Obstructions*

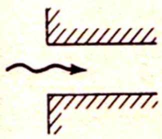


$\frac{z}{d}$	1.00	0.80	0.60	0.50	0.40	0.20	0.10
k_m	0.00	0.19	0.90	2.10	5.00	25.0	100

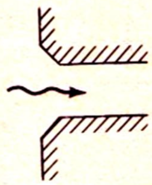
3. *Entrances*



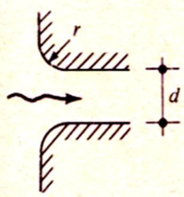
$k_m = 1.0$



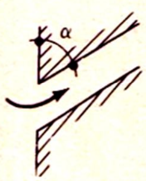
$k_m = 0.50$



$k_m = 0.25$

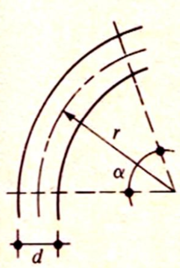


$\frac{r}{d}$	0.08	0.16	0.20	0.25 and more
k_m	0.15	0.06	0.03	0.0



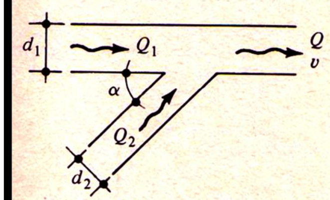
α	85°	75°	60°	45°
k_m	0.53	0.59	0.70	0.74

4. *Bends*

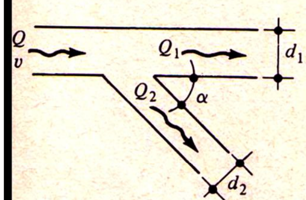


$\frac{r}{d}$	α			
	90°	60°	45°	22.5°
1.0	0.30	0.25	0.21	0.13
2.0	0.16	0.13	0.11	0.05
3.0	0.12	0.10	0.08	0.04
4.0	0.11	0.09	0.08	0.04
5.0	0.09	0.07	0.06	0.03
6.0 and more	0.08	0.07	0.06	0.03

5. *Branches*



$\alpha = 90°$	Q_2/Q	0.00	0.20	0.50	1.00
	Q_1/Q	1.00	0.80	0.50	0.00
$d_1 = d_2$	k_m	− 0.98	− 0.25	0.45	1.12
		0.00	*0.30*	*0.52*	*0.56*
$d_1 = 2d_2$	k_m	− 0.75	0.55	4.00	16.0
		0.25	*0.50*	*0.95*	*1.40*
$\alpha = 45°$ $d_1 = d_2$	k_m	− 0.91	− 0.37	0.12	0.38
		0.05	*0.18*	*0.13*	*− 0.54*
$d_1 = 2d_2$	k_m	− 1.00	0.15	3.50	11.0
		0.00	*0.06*	*− 0.60*	*− 4.10*



$\alpha = 90°$	Q_2/Q	0.00	0.20	0.50	1.00
	Q_1/Q	1.00	0.80	0.50	0.00
$d_1 = d_2$	k_m	− 0.98	0.87	0.87	1.27
		0.03	*− 0.03*	*0.02*	*0.35*
$d_1 = 2d_2$	k_m	1.30	1.90	5.00	21.0
		0.15	*− 0.11*	*0.15*	*0.28*
$\alpha = 45°$ $d_1 = d_2$	k_m	0.90	0.68	0.42	0.47
		0.04	*0.06*	*0.01*	*0.33*
$d_1 = 2d_2$	k_m	0.90	0.50	0.86	10.0
		0.00	*− 0.04*	*0.01*	*0.33*

(2.6) Tables of minor losses

2.7 Resistance Coefficients for Valves & Fittings

Possible to find a length of pipe that for the same flow rate would produce same head loss as a valve or fitting.

$$\boxed{H_{L\,(\text{Valve or Fitting})} = H_{L\,(\text{Pipe})}} \quad \text{……………………. (2.22)}$$

From Eq(2.9)and Eq(2.16)

$$\boxed{K\frac{V^2}{2g} = f\,\frac{L}{D}\left(\frac{V^2}{2g}\right)} \quad \text{……………………. (2.23)}$$

Thus.

$$\mathbf{k} = \left(\frac{L_e}{D}\right)\mathbf{f} \quad \text{..................................} \quad (2.24)$$

Le is the equivalent length, defined as the length of a straight pipe which would produce the same total head loss as a device such as valve, fitting.

V is the average velocity in the pipe attached to the device.

f is the friction factor that can be obtained from the Moody diagram.

$\left[\frac{L_e}{D}\right]$ ratio for different devices are given in below table.

Type	Equivalent Length in Pipe Diameters L_e/D
Globe valve—fully open	340
Angle valve—fully open	150
Gate valve—fully open	8
—¾ open	35
—½ open	160
—¼ open	900
Check valve—swing type	100
Check valve—ball type	150
Butterfly valve—fully open, 2–8 in	45
—10–14 in	35
—16–24 in	25
Foot valve—poppet disc type	420
Foot valve—hinged disc type	75
90° standard elbow	30
90° long radius elbow	20
90° street elbow	50
45° standard elbow	16
45° street elbow	26
Close return bend	50
Standard tee—with flow through run	20
—with flow through branch	60

Table (2.4) Ratio for different devises

Total head losses = major losses+ miniors losses

$$H_L = h_m + h_f \quad \text{.......................................} (2.25)$$

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Equipment

The **PPR** fluid model construct from ,two items Pressure gauges, Pressure pump , measuring instruments, Vernier calipers, elbows, valves, tape, , tanks, and Stop watch

Fig 3.1:

A horizontal and straight pipes and fitting systems was connected between two branches A and B see figure(3.2), branch A construct with 16 elbows and branch B has pipe length 8.05 meter and 16 elbows also were set up in horizontal location and its two ends were connected to pumps with some additional flexible pipes. Two pressure gauges were connected to the two point 'sone at pump and the other at the end of two branches .All the connections bonded by wearing and a suitable O-rings and bolts. The water inside the system was maintained at room-temperature and without added heat and cool system .The fluid flows throughout the system, it is made to travel from a reservoir/ through different experimental equipment into reservoir again as closed system.

3.1.2Materials

The Water fluid was use in all experiments the dimension of the pipe

size	Internal diameter(cm)	Outside diameter(cm)	Wall thickness (cm)	Pipe length (m)
½ inch	1.42	2.03	0.305	8.05

Table (3.1): dimension of pipe

3.2 Methods

The experiment was done in the two branching system at different flow rate by using the valve at random its position, the all measurement pressure volume and time were monitored.

3.2.1 Branch (A) elbow model

Table (3.2): elbows model system

NO	P1(psi)	P2(psi)	volume(lit)	time(s)
1	17.5	17	3	49.8
2	16	15	3	36.4
3	15.2	14	3	30
4	14.2	12	3	26.8
5	12.7	10	3	22.4
6	12.3	9	3	21
7	11.5	7.8	3	19.1
8	10.5	7	3	18.7
9	9.5	6	3	17.6

The pressure was converted to Pascal unit minor head losses was calculated assumed that no major losses neglecting small length between elbows fitting by using e.g(2.54) .

$$k_m = \sum_{i=1}^{16} k \frac{V^2}{2g}$$

The results was shown in t…..

The results of minor head losses, volume flow rate, and Renolds number were calculated see that in tables (4.1,) and set of figures (4.1 , 4.2)

The results of minor and major head losses, volume flow rate, Renolds number were calculated see that in tables (4.1,)and set of figures(4.3 ,4.4)

3.2.1 Branch (B) elbow and pipes model

Table (3.3): elbows and pipes model system

NO	P1(psi)	P2(psi)	volume(lit)	time(s)
1	20.3	20	3	84
2	19	18	3	55.5
3	17.5	16	3	39.75
4	16.4	15	3	35.6
5	15	13	3	29.3
6	13.5	11	3	24.9
7	13	10	3	24.5
8	11.7	8	3	22
9	10.8	6.5	3	19.7

The pressure was converted to Pascal unit major head losses was calculated and take to account a k value resulted in table(4.1) neglecting small length between elbows fitting and by using e.g(2.17) .

$$H_L = (\sum_{i=1}^{16} k + f\frac{L}{d})\frac{V^2}{2g}$$

Where f=friction factor, L =the length of pipe

The results of major head losses, volume flow rate, Renolds number, friction factor were calculated see that in tables (4.3) and set of figures (4.2)

The experimental friction factor obtained and combined with a value of Blasius equation eq (2.12) the Colebrook Equation was used to predict e/d ration for given experimental value and finally the Miller Equation was use to verify the results.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Results of branch (A) elbow model

Table (4.1):elbow model calculations

P_1(pa)	P_2(pa)	Q(m3/s)	V(m/s)	Re	Pressure drop (bar)	h_m(m)	$v^2/2g$(m)	K
123000.3	119486	6.0241E-05	0.380579654	6072.169753	3514.295439	0.358236028	0.007382307	48.52629473
112457.5	105428.9	8.24176E-05	0.520683152	8307.528948	7028.590878	0.716472057	0.013818091	51.85029231
106834.6	98400.27	0.0001	0.631762225	10079.80179	8434.309054	0.859766468	0.020342686	42.26415567
99805.99	84343.09	0.00011194	0.70719652	11283.36021	15462.89993	1.576238525	0.025490669	61.83590349
89263.1	70285.91	0.000133929	0.846110123	13499.73454	18977.19537	1.934474554	0.036488397	53.01615687
86451.67	63257.32	0.000142857	0.902517464	14399.71684	23194.3499	2.364357788	0.041515687	56.95094976
80828.8	54823.01	0.000157068	0.992296688	15832.14941	26005.78625	2.650946611	0.050186173	52.82225049
73800.2	49200.14	0.000160428	1.013522286	16170.80501	24600.06807	2.507652199	0.052356138	47.89605008
66771.61	42171.55	0.000170455	1.076867429	17181.48033	24600.06807	2.507652199	0.059105171	42.42695093

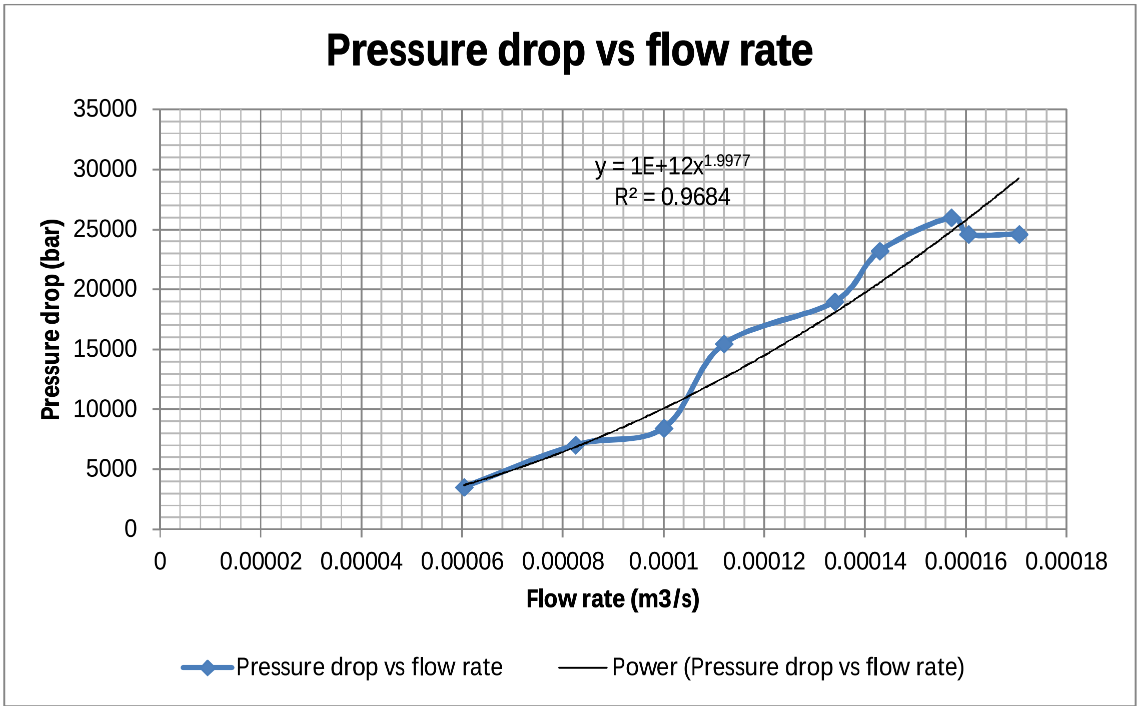


Figure 4.1:pressure drop vs flow rate for elbow model

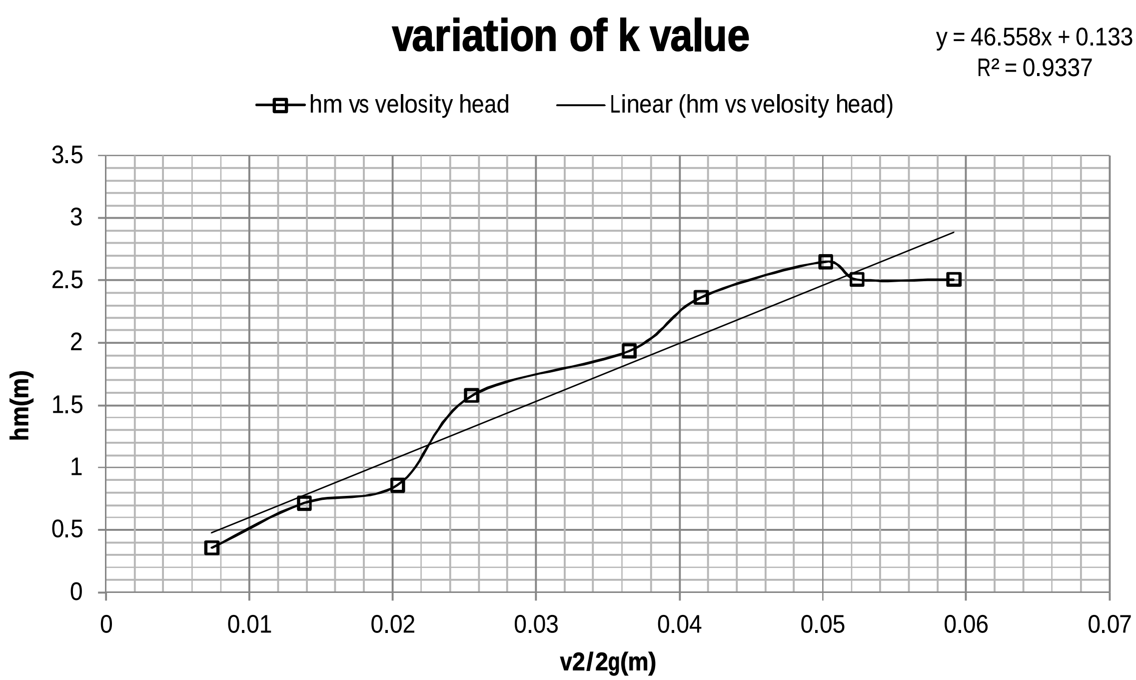


Figure 4.2:hm vs velocity head

$$the\ average\ k\ value\ of\ the\ elbow = \frac{\mathbf{50.8432227}}{\mathbf{16}} = \mathbf{3.177701419}$$

4.1.1 Discussion of branch (A) elbow model

The value was obtained 3.2 the high value compared with most materials resulting to welding .

4.1.2 Results of branch (B) elbow and pipe model

Table (4.2):elbow and pipe model calculations

P_1(pa)	P_2(pa)	Q(m3/s)	V(m/s)	Re	Pressure drop (bar)	H_L(m)	$v^2/2g$(m)	f experimental
142680.3948	140571.8176	3.57143E-05	0.225629366	3.60E+03	2108.577263	0.214941617	0.00259473	0.056437543
133543.2267	126514.6358	5.40541E-05	0.341493095	5.45E+03	7028.590878	0.716472057	0.005943809	0.122944961
123000.3404	112457.4541	7.54717E-05	0.476801679	7.61E+03	10542.88632	1.074708085	0.011587148	0.073922532
115268.8904	105428.8632	8.42697E-05	0.532383897	8.49E+03	9840.027229	1.00306088	0.014446107	0.032794879
105428.8632	91371.68142	0.000102389	0.64685552	1.03E+04	14057.18176	1.432944114	0.021326303	0.028837775
94885.97686	77314.49966	0.000120482	0.761159307	1.21E+04	17571.4772	1.791180142	0.02952923	0.017312791
91371.68142	70285.90878	0.000122449	0.773586398	1.23E+04	21085.77263	2.149416171	0.030501321	0.034620459
82234.51327	56228.72703	0.000136364	0.861493943	1.37E+04	26005.78625	2.650946611	0.03782731	0.033933605
75908.78148	45685.84071	0.000152284	0.962074454	1.53E+04	30222.94078	3.080829845	0.047175701	0.025510989

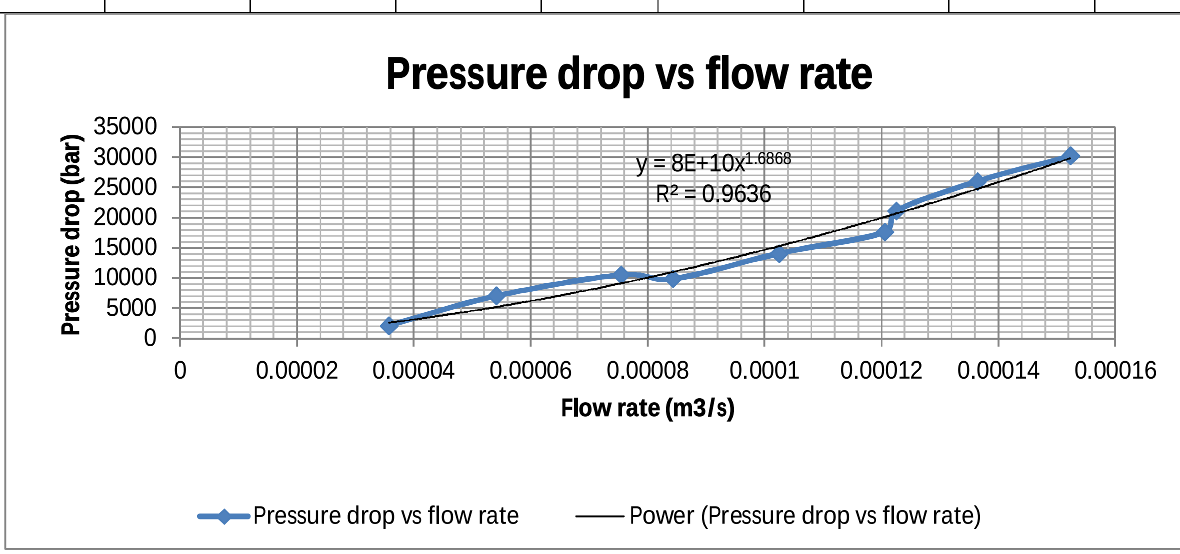


Figure [4.3: pressure drop vs flow rate for elbow and pipe model

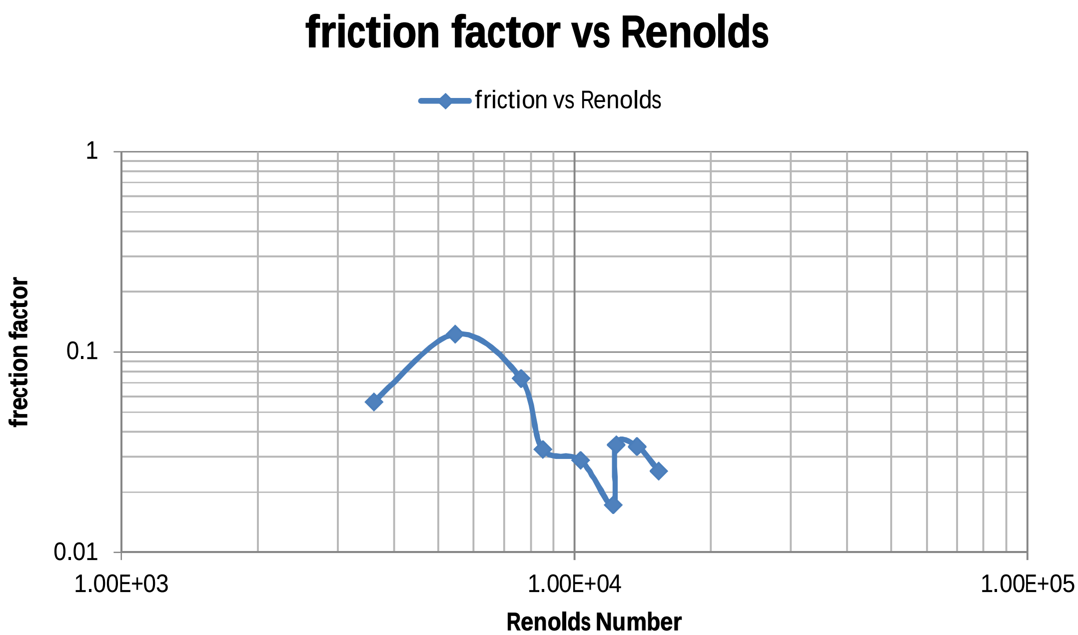


Table (4.3):experimental friction factor and formula in literature

Friction factor Experimental	Friction factor Blasius Equation	e/d value Colebrook Equation	Miller Equation
0.056437543	0.040847265	0.017	0.045119716
0.122944961	0.036827006	0.1	0.040604073
0.073922532	0.033878755	0.05	0.037676333
0.032794879	0.032957606	0.001	0.036828633
0.028837775	0.031391355	0.0006	0.035461512
0.017312791	0.030139983	-	-
0.034620459	0.030018203	0.003	0.034340843
0.033933605	0.029221253	0.004	0.033724273
0.025510989	0.028425605	0.004	0.033133797

4.1.2 Discussion of branch (B) elbow and pipe model

Table (4.3) it obvious that The average value was obtained of 16 elbows 50. the high value compared with most materials resulting to welding .

CHAPTER FIVE
CONCLOSION

The conclusions of this study are summarized as folows:

- PPR pipes network consist of two branches A,B .Branch A consist of 16 elbows which was used to calculate the (K) value for elbow which was 2.9 →3.2 .
- Branch B consist of 8.05 meter from the length of the pipe and 16 elbows has been used to find friction factor.
- The equation Blasius give good results which neglected roughness.
- The model of Colebrook equation was used to find the pipe roughness which was 0.004 .
- The experimental values was confirmed using Miller equation.
- This model can calculate pressure losses and it can be used in the experimental libratory of fluid mechanics.

RECOMMENDATION

1\ To make sure of the absence of any fractions during the welding.

2\ Different kinds of valves and fittings can be used to obtain different results of losses .

3\ Other kinds of plastic pipes (PVC,PEX,HDPE) can be studied practically.

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